Analysis of Global Positioning System (GPS) signals from land for soil moisture determination and topography mapping

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Agenda

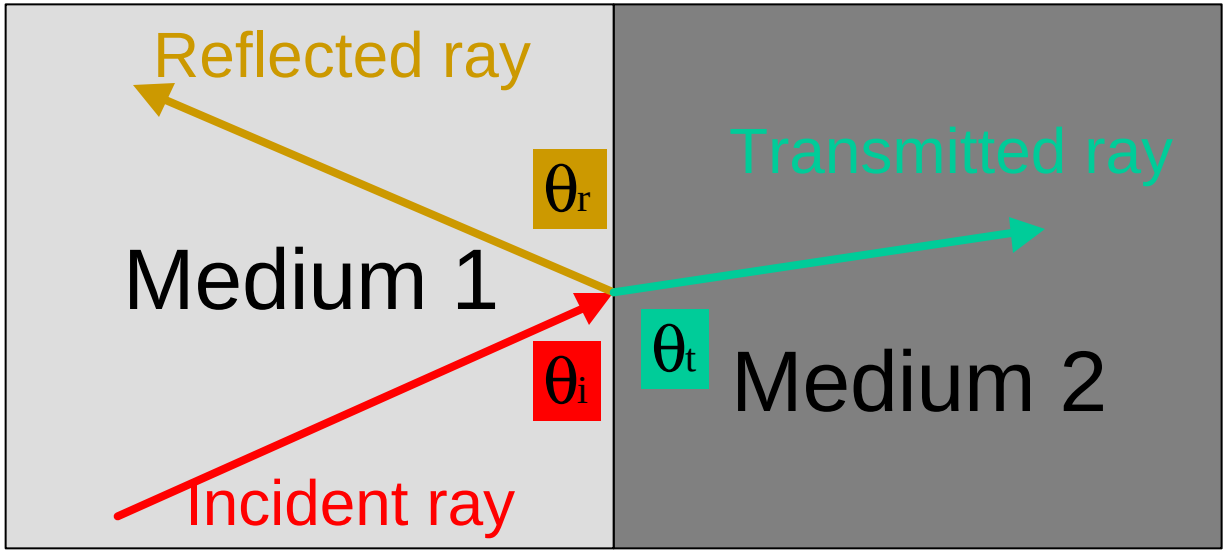
- Objective
- Background
- Data acquisition and hardware
- Soil Moisture study in TX and NM
- Topography observations in TX, NM
- GPS reflections through ice and snow in CO
- Current and future work
- Conclusions
- Open forum

Objective

To investigate the use of reflected GPS signals as a remote sensing tool to determine soil moisture

Background

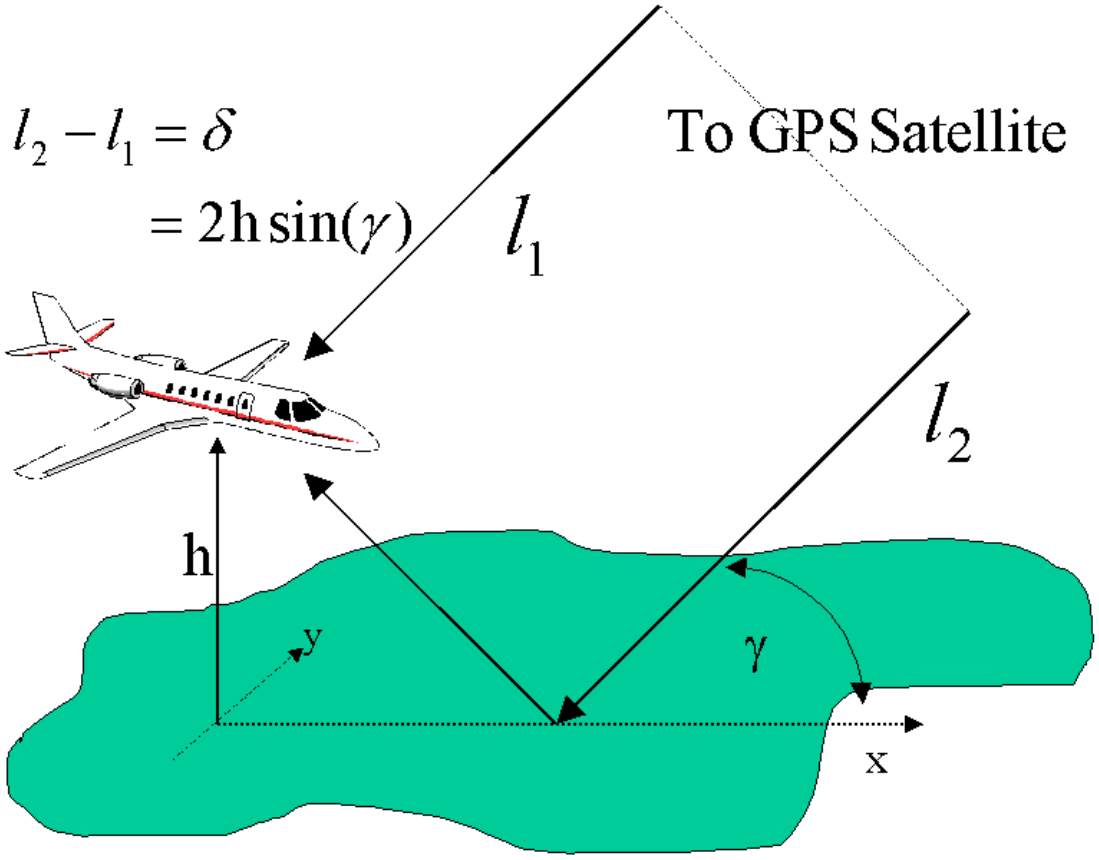
Reflection takes place when wave travels from medium 1 to medium 2



$q_i = q_r$ (Snell's law of reflection)

Background

Geometry of surface reflections



Background

Fresnel reflection coefficient

$$\Gamma = \frac{E_r}{E_i} = \frac{-\left(\frac{e_2}{e_1}\right) Cos\ \ q_i + \sqrt{\left(\frac{e_2}{e_1}\right) - Sin^{\ 2} q_i}}{\left(\frac{e_2}{e_1}\right) Cos\ \ q_i + \sqrt{\left(\frac{e_2}{e_1}\right) - Sin^{\ 2} q_i}}$$

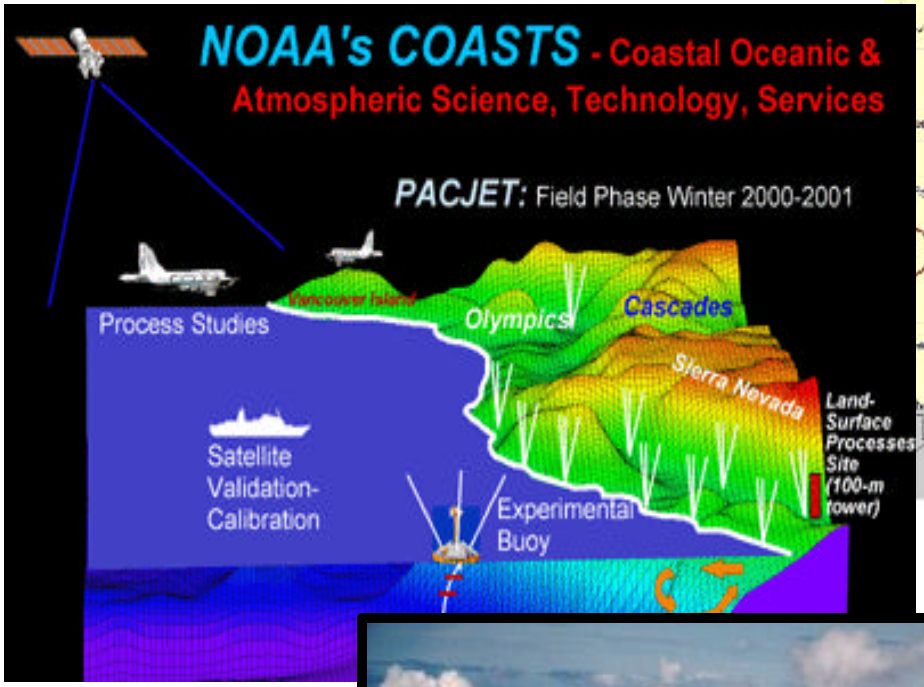
Sea-water	Wet-soil	Very dry soil
$\frac{E_r}{E_i} \cong 80\ \%$	$\frac{E_r}{E_i} \cong 72\ \%$	$\frac{E_r}{E_i} \cong 18\ \%$

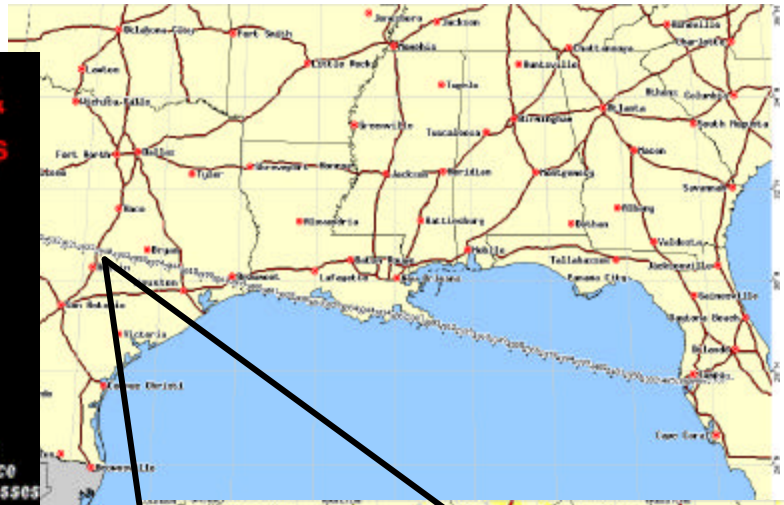
For $q_i \cong 0$

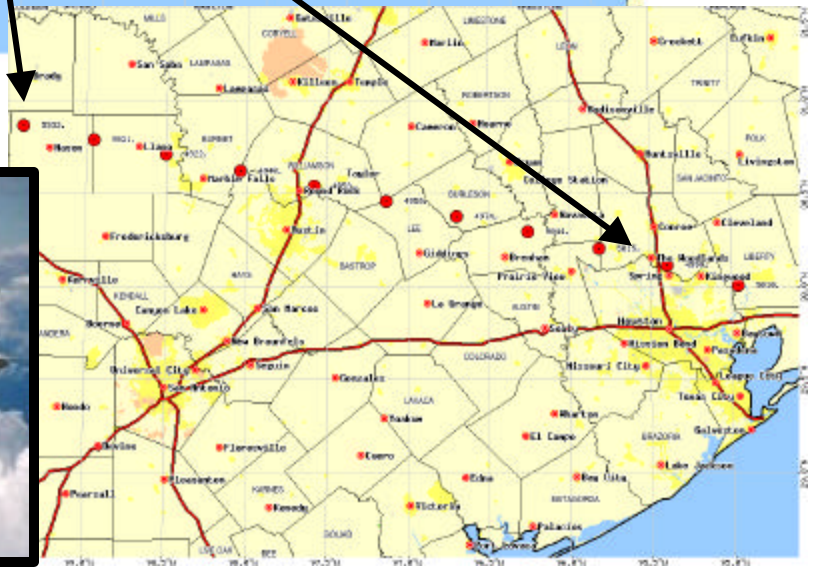
ε: Permitivity of medium

Data acquisition

PACJET Mission





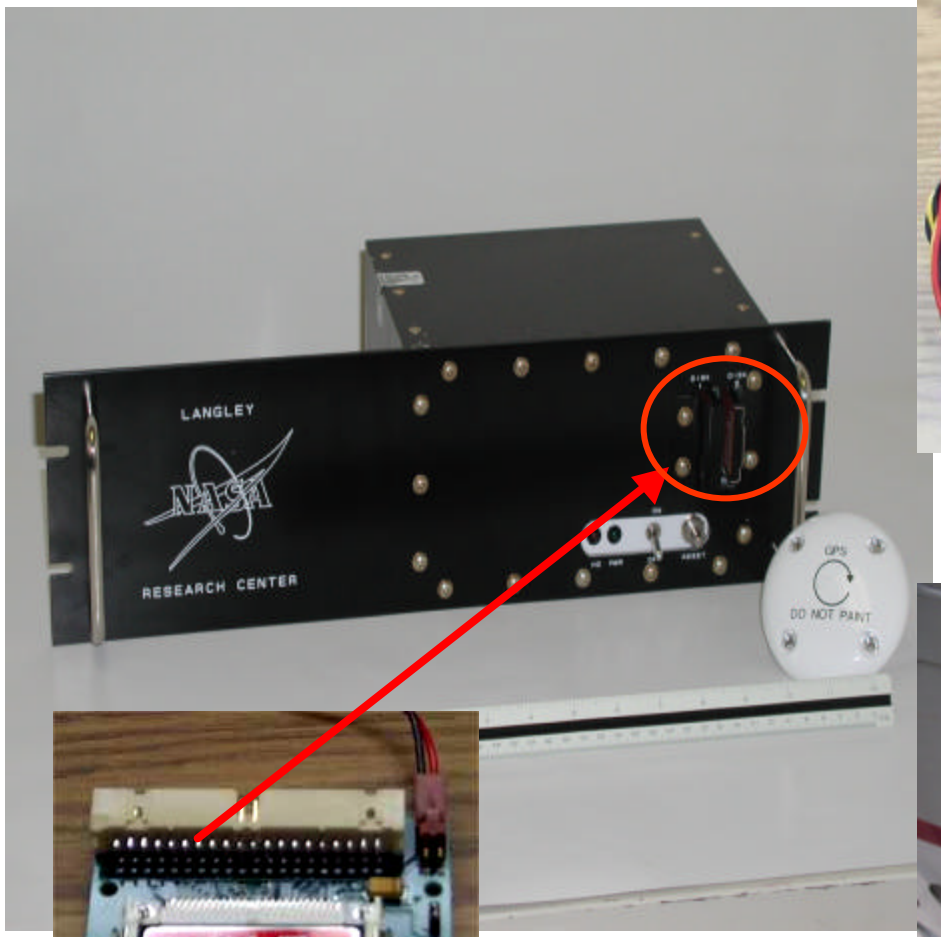


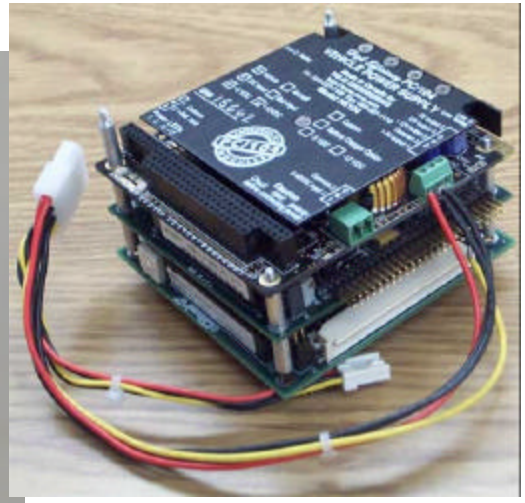
Hardware

~ 9 watts

< 3 lbs

8 x 6.75 x 6 in





Data format

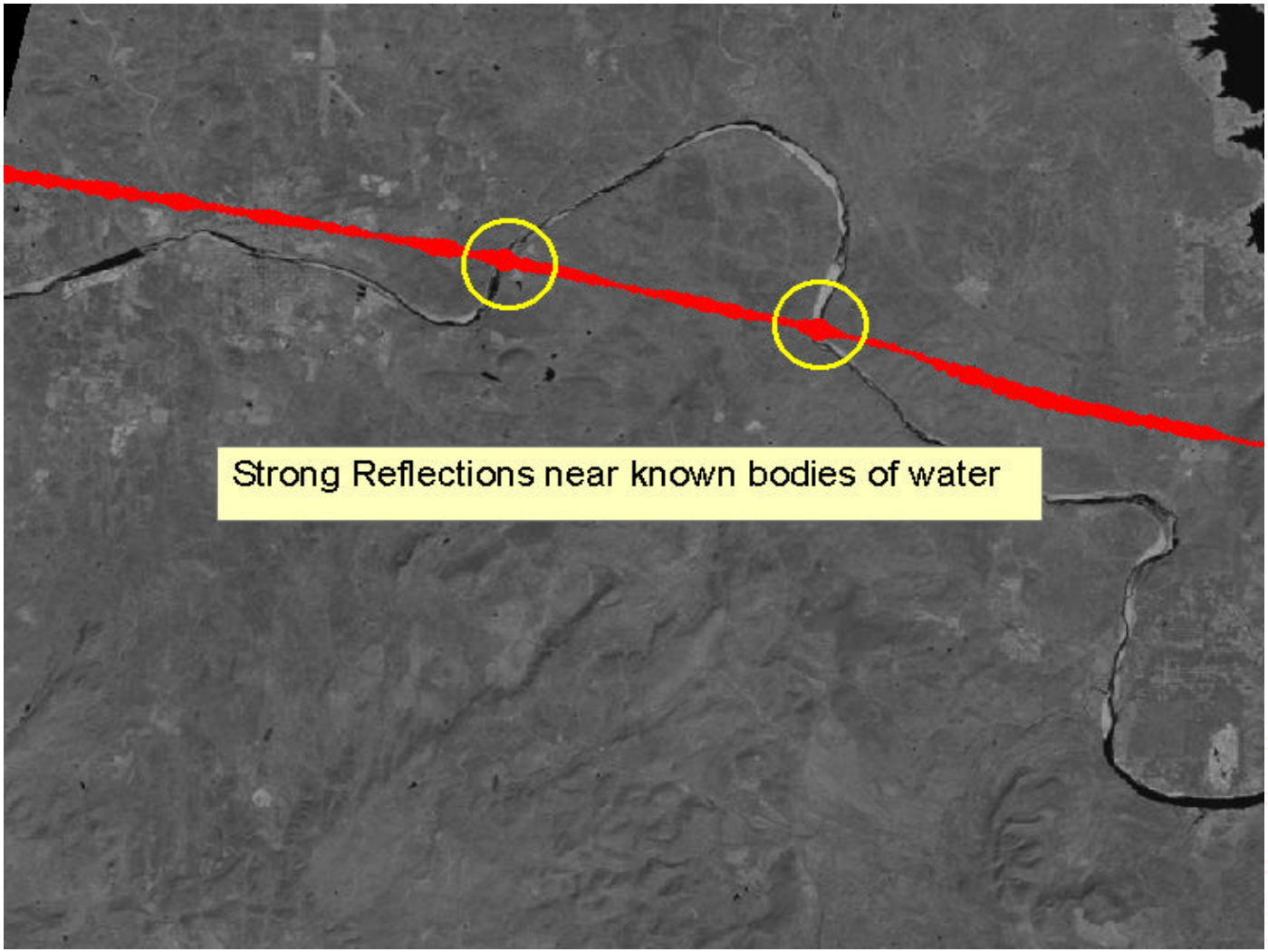
Long	Lat	h	γ	ϕ	δ	P
–99.1523,	30.2455,	5849,	68.17,	208.74,	1532,	1238568

$$\Delta lat = \frac{h \cdot Cot(g) \cdot Cos(f)}{\mathrm{Re}}$$

$$\Delta long = \frac{h \cdot Cot(g) \cdot Sin(f)}{\mathrm{Re} \cdot Cos(Lat)}$$

Long: Longitude of receiver
Lat: Latitude of receiver
h: Elevation of receiver (given by GPS)
γ: Elevation angle of satellite
ϕ: Azimuth angle of satellite
δ: Delay of reflected signal
P: Amplitude of reflected signal
Re: Radius of Earth
Δlat: latitude difference from receiver
Δlong: longitude difference from receiver

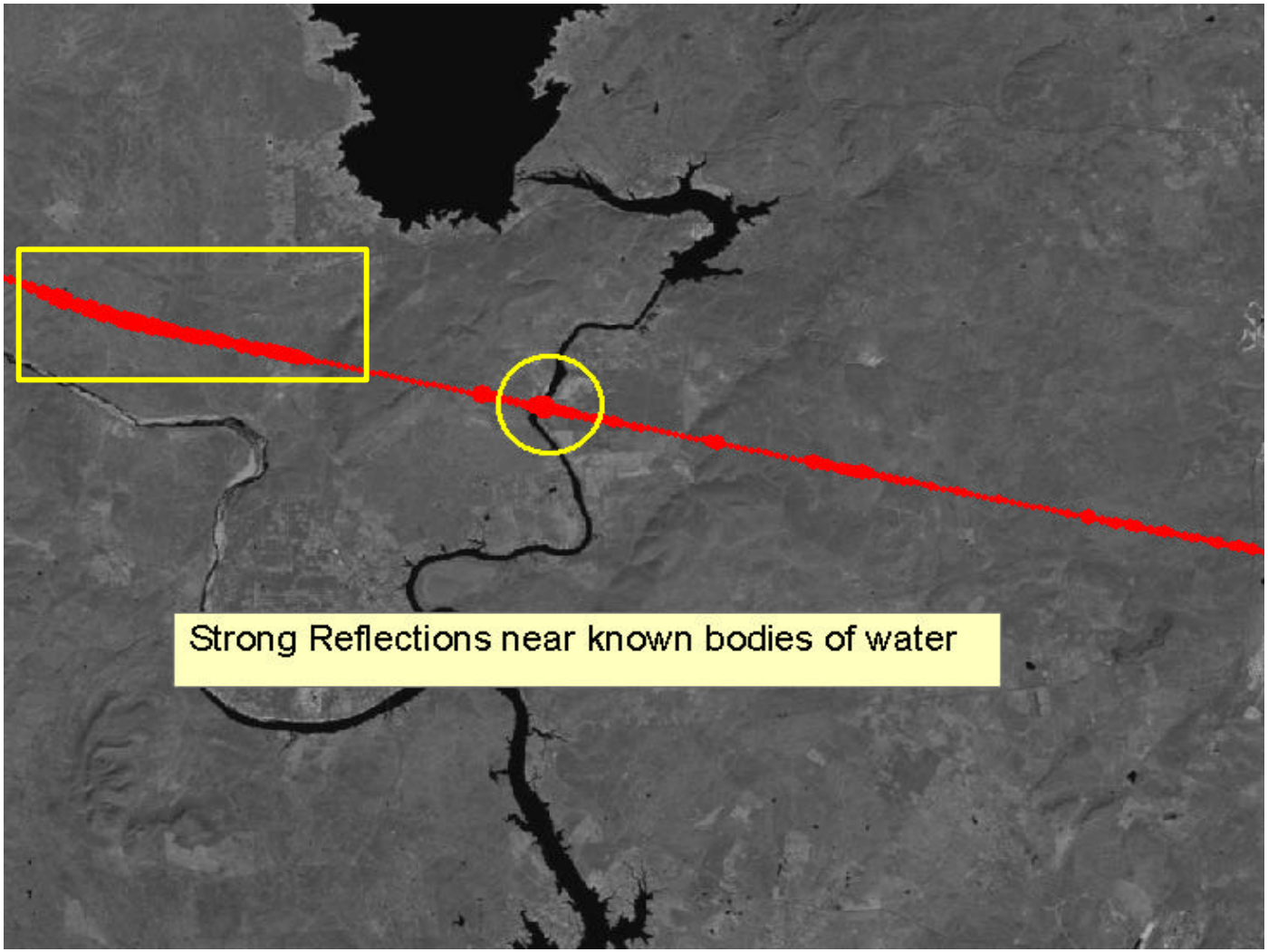
Soil Moisture in Texas



Relative reflected strength over Texas. Big dots represent stronger signals

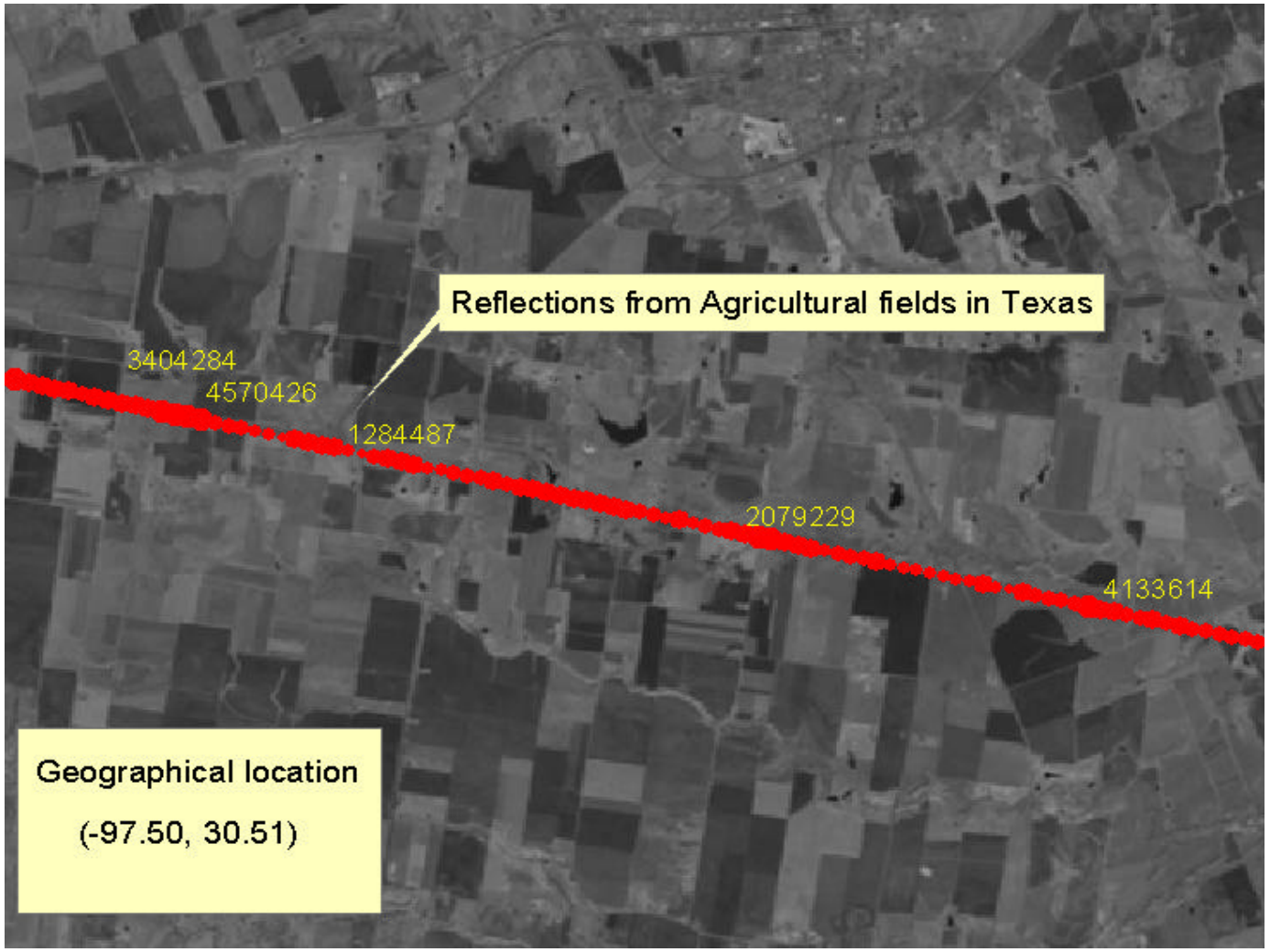
Strength
104708 - 1181600
1181601 - 1782251
1782252 - 2475791
2475792 - 3364384
3364385 - 4632775
4632776 - 6582363
6582364 - 9835478
9835479 - 16321303

Soil Moisture in Texas



Correlation of reflected signals with known bodies of water

Soil Moisture in Texas



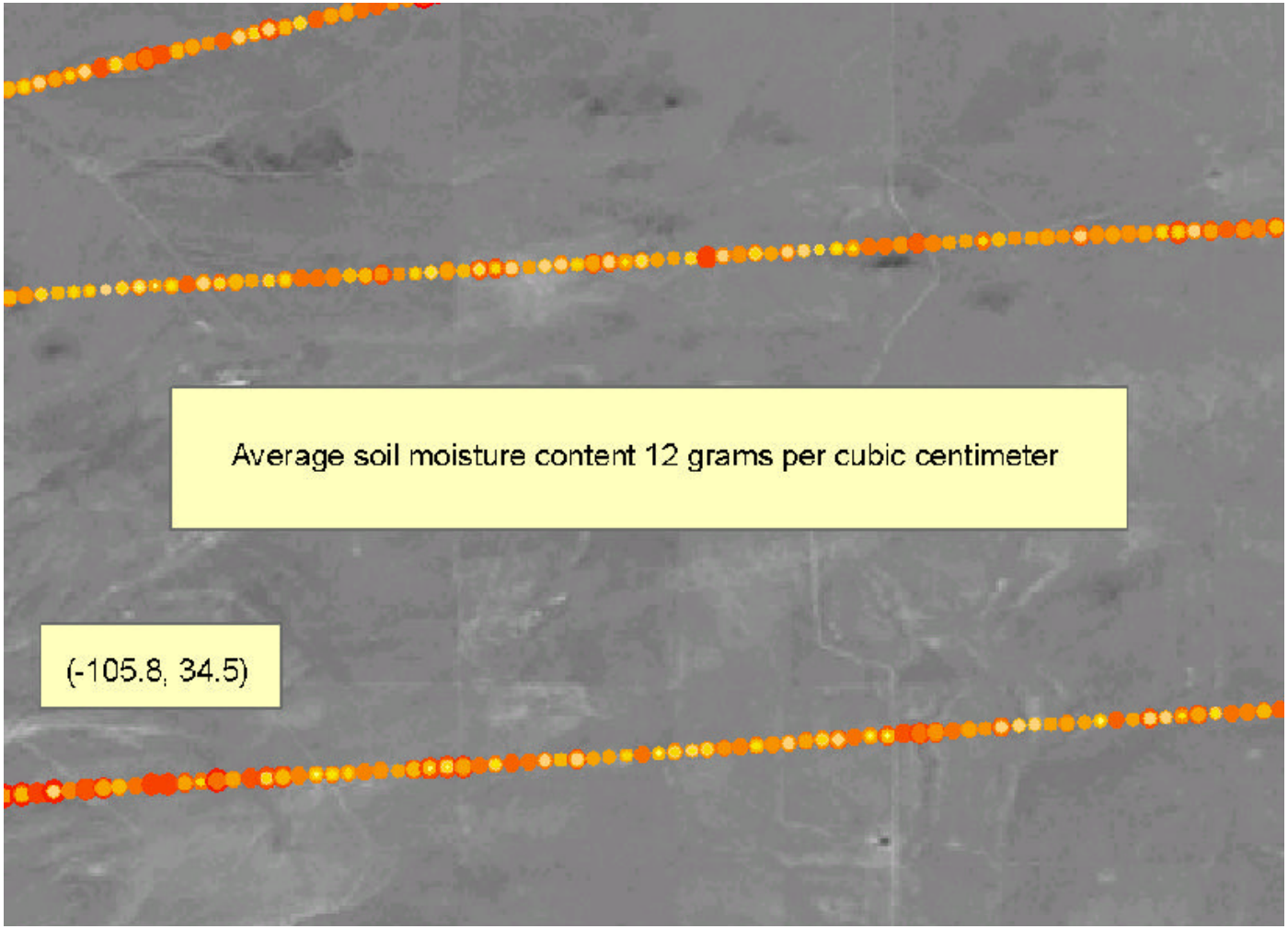
Reflections from high Soil moisture area

35g/cm^3 in the average

Average strength

1,160,445.29

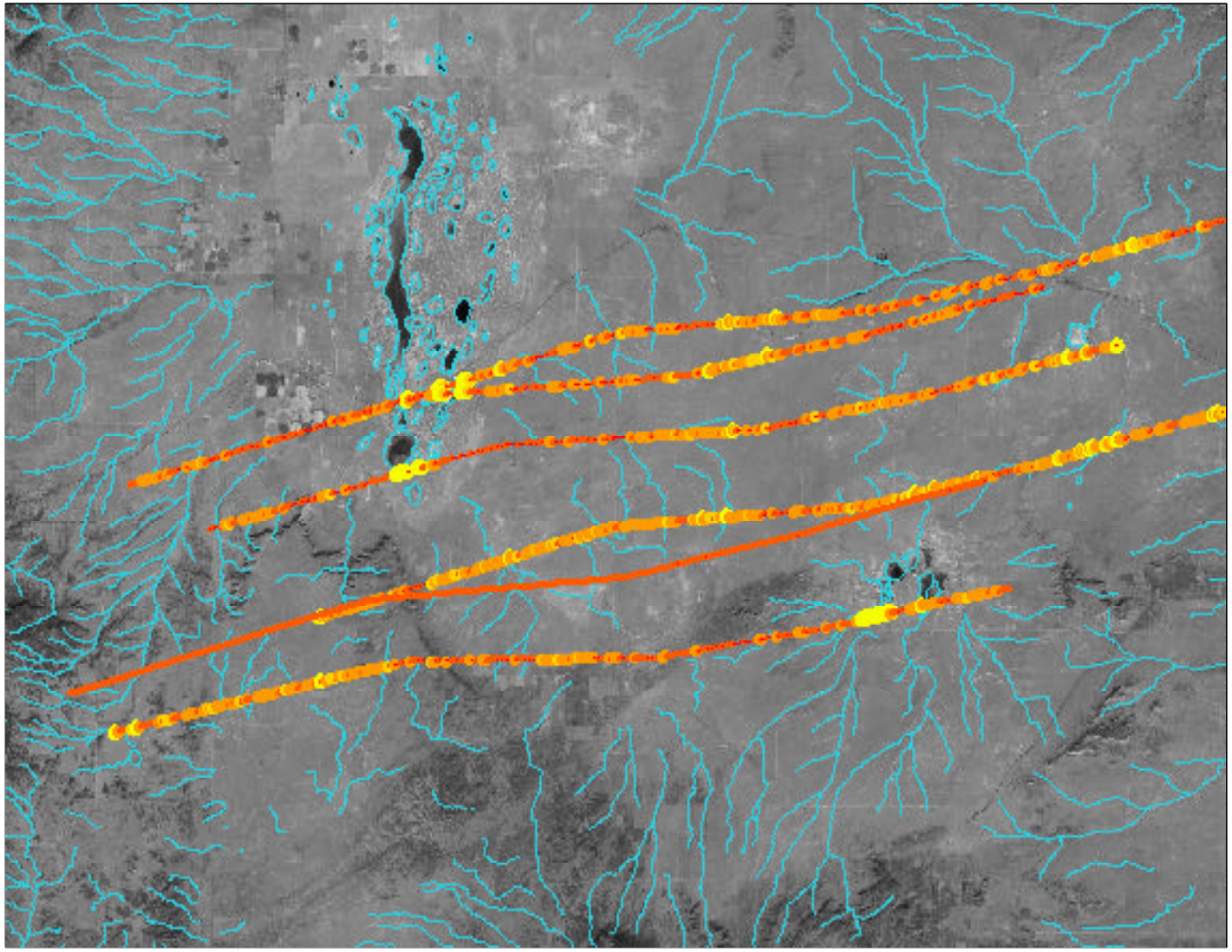
Soil Moisture in New Mexico



GPS signals reflected from low soil moisture, 12 g/cm^3 near Adams Ranch, NM

- 147136 - 1890336
- 1890337 - 2163904
- 2163905 - 2390816
- 2390817 - 2596928
- 2596929 - 2799310
- 2799311 - 3010848
- 3010849 - 3234806
- 3234807 - 3476800
- 3476801 - 3756750
- 3756751 - 4090656
- 4090657 - 4519616

Soil Moisture in New Mexico



Average signal strength in New Mexico 346,679.69

Background

Fresnel reflection coefficient

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Sea-water	Wet-soil	Very dry soil
$\frac{E_r}{E_i} \cong 80\ \%$	$\frac{E_r}{E_i} \cong 72\ \%$	$\frac{E_r}{E_i} \cong 18\ \%$

For $q_i \cong 0$

ε: Permitivity of medium

Soil Moisture Observations

- Texas

Avg. soil moisture: 35 g/cm^3

Average strength: 1,160,445.29

$$\frac{Signal\,Strength}{Soil\,Moisture} \cong 34{,}110.38$$

- New Mexico

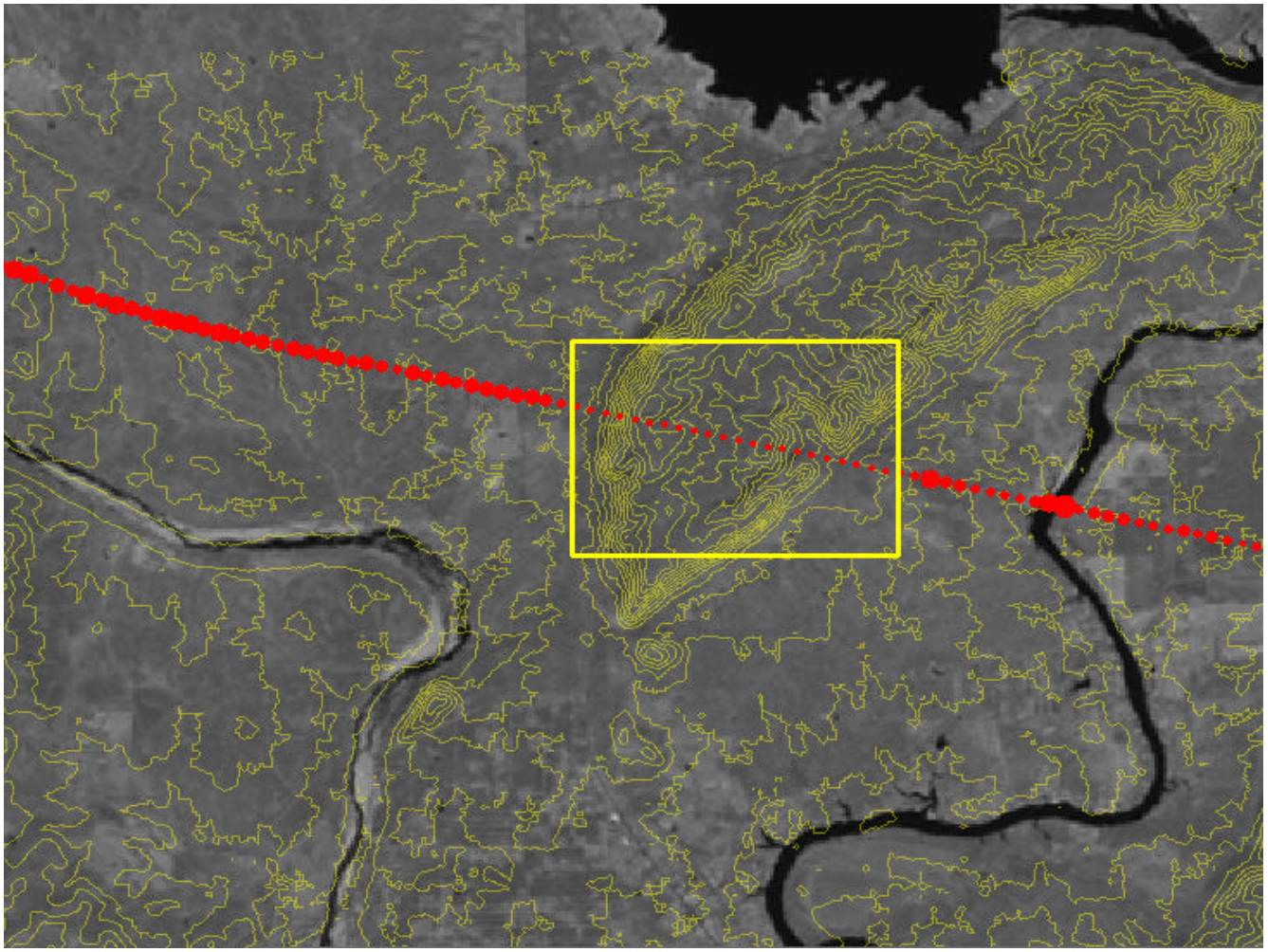
Avg. soil moisture: 12 g/cm^3

Average strength: 346,679.69

$$\frac{Signal\,Strength}{Soil\,Moisture} \cong 31{,}260.57$$

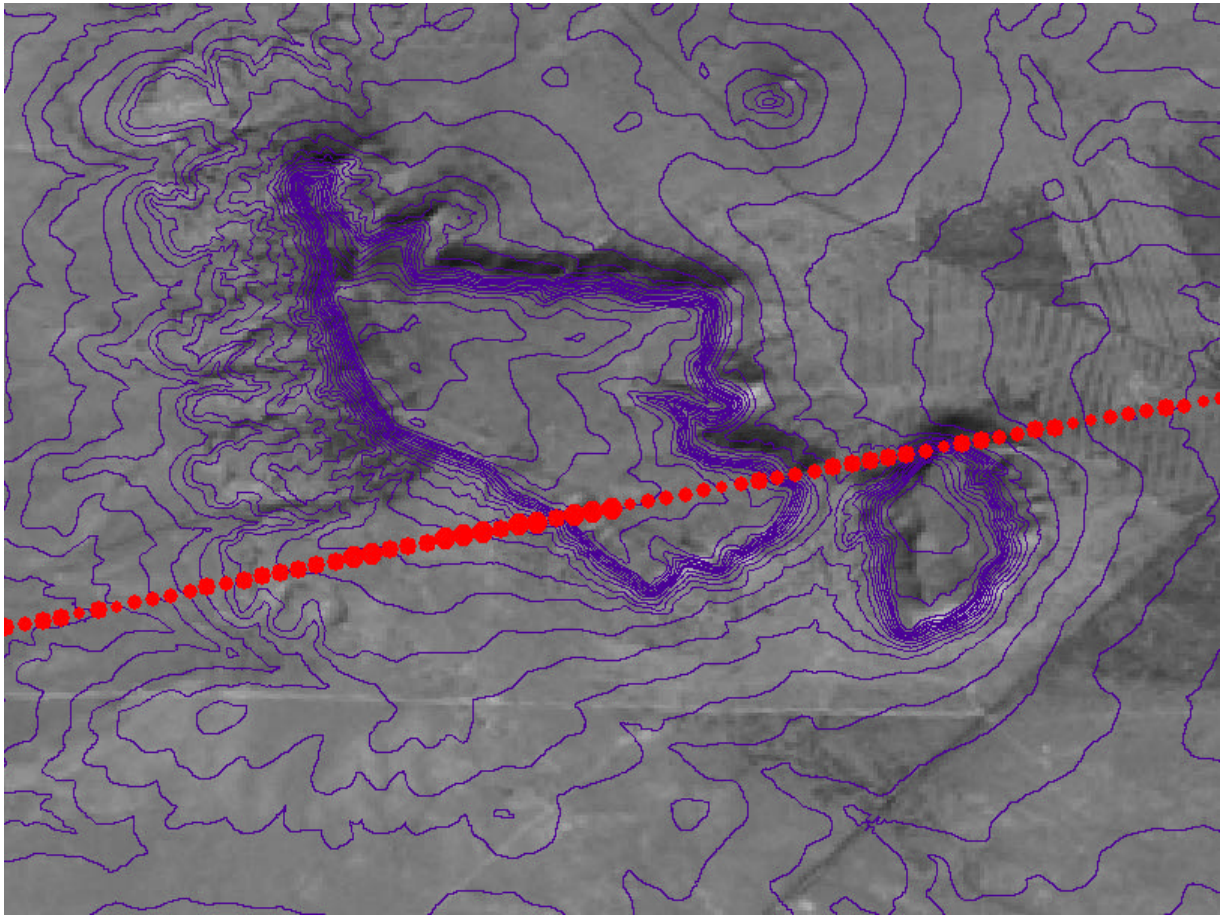
Soil Moisture values were collected from USDA's SCAN home page at http://www.wcc.nrcs.usda.gov/scan/

Topography in Texas

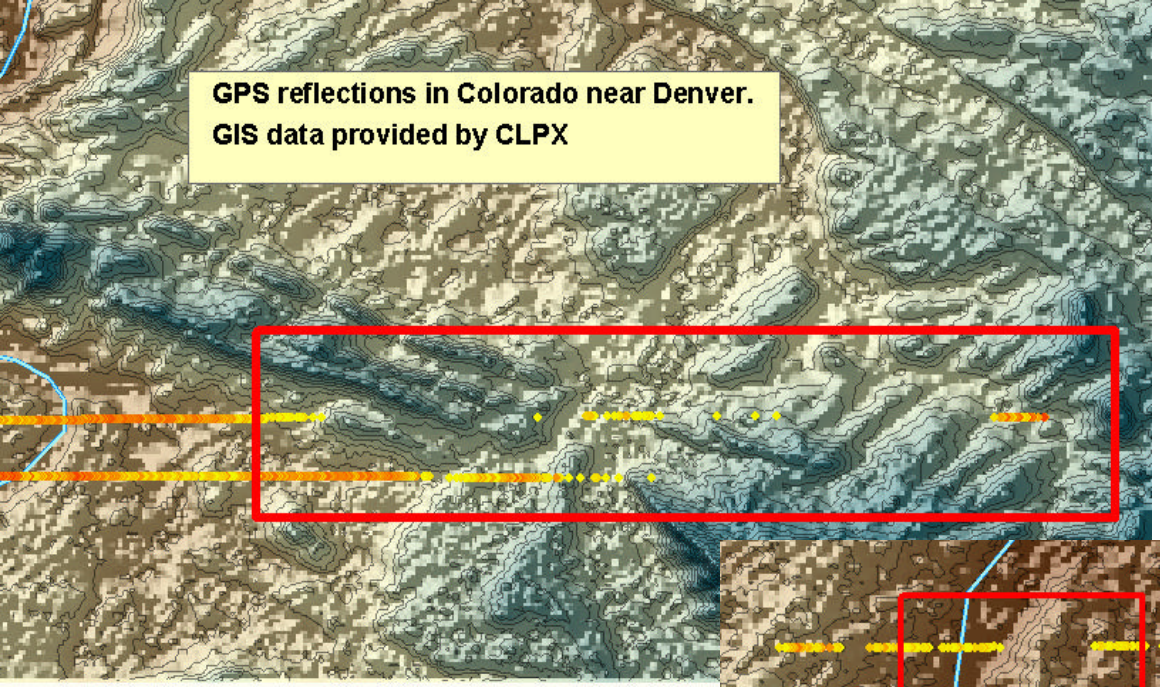


Topography effects on GPS reflected signals

Topography in New Mexico

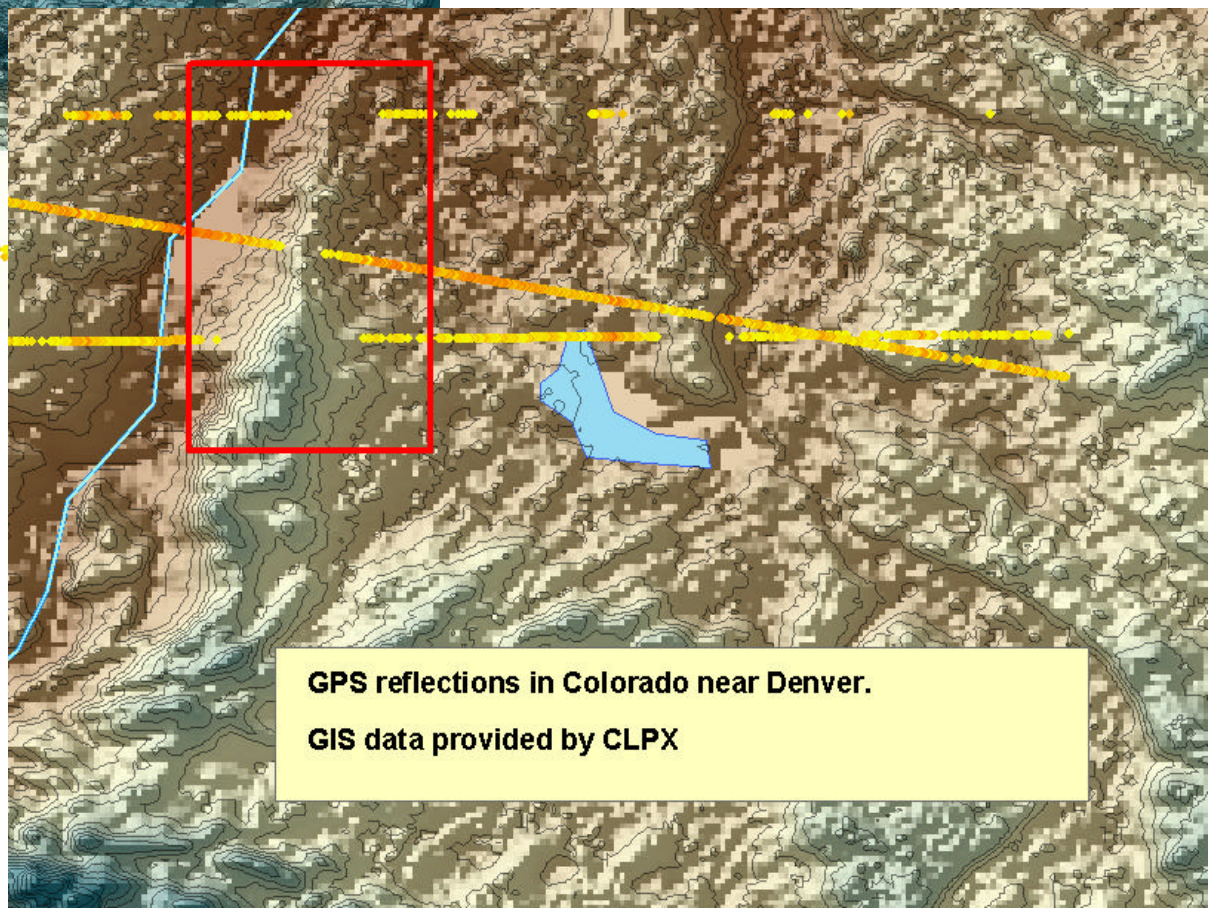


Satellite-receiver position and surface normal: primary factors on reflection propagation



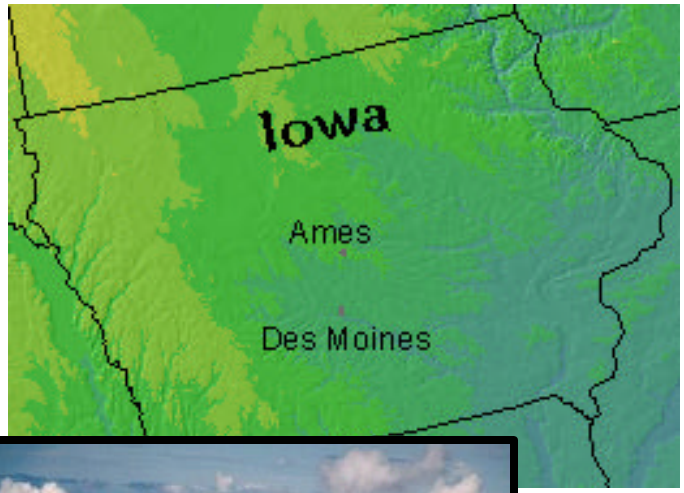
CLPX Experiment
near Denver, CO

Satellite-receiver position and surface normal: primary factors on reflection propagation



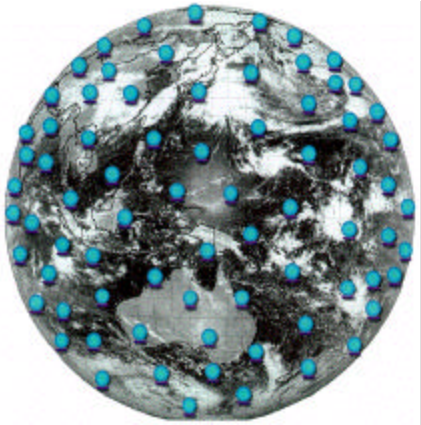

SSB
SPACECRAFT & SENSORS BRANCH

Current/Future work



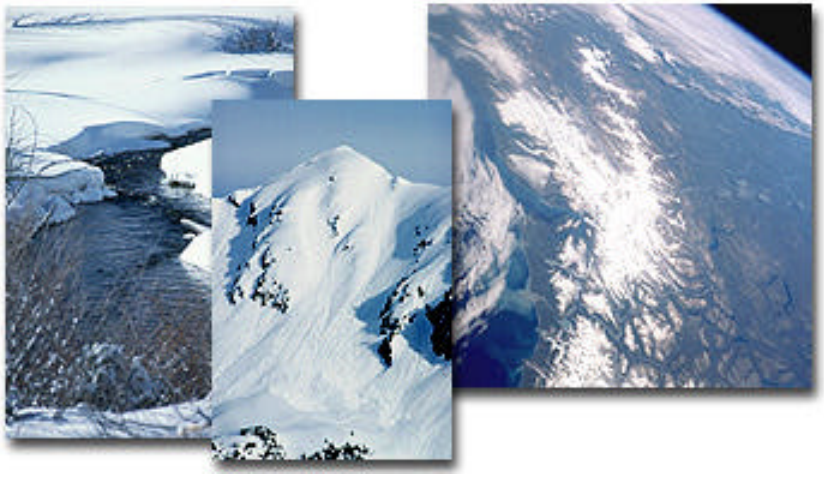
ULDB Experiment

SMEX02

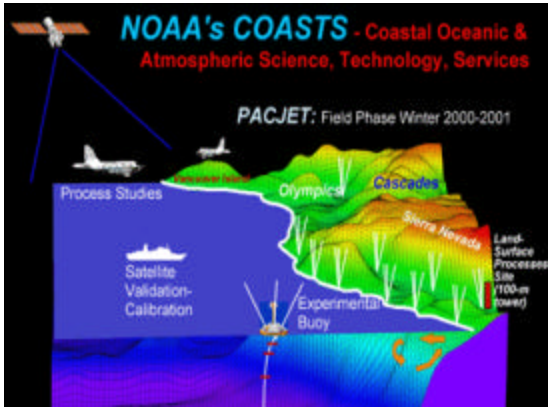


Global Air-ocean
IN-situ System

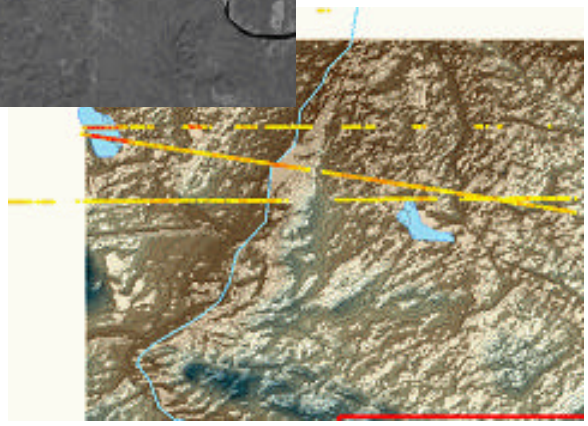
Current/Future work



CLPX03



PACJET02



Conclusion

GPS signals appear strongly related to soil moisture including penetration of snow and ice

Phenomena of soil moisture reflectance complicated over busy topography

Current research objectives are aimed at better understanding of the interrelation of the various factors influencing signal level

Open Forum

GPS Reflections Home Page

http://centauri.larc.nasa.gov/gps